Whistler Observations on DEMETER Compared with Full Electromagnetic Wave Simulations Sferic Earth Ionosphere (60 km – 80 km) 0 + Whistler Lightning

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AE31B-3415: Whistler Observations on DEMETER Compared with Full Electromagnetic Wave Simulations

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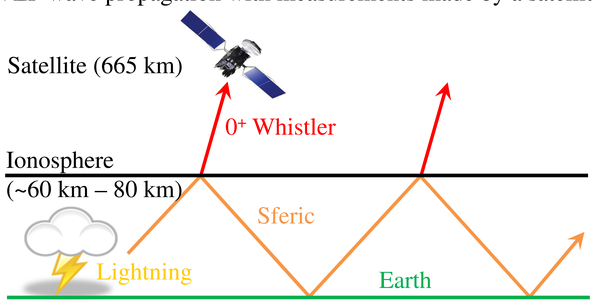
Introduction

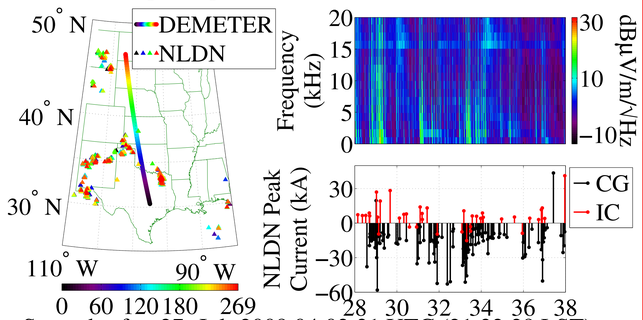
Goal: Compare the field strengths of lightning-induced 0^+ whistlers predicted by a numerical model of trans-ionospheric VLF wave propagation with measurements made by a satellite.



Energy injected into the magnetosphere by whistlers from lightning plays an important role in Earth's inner radiation belt, so accurate models are needed

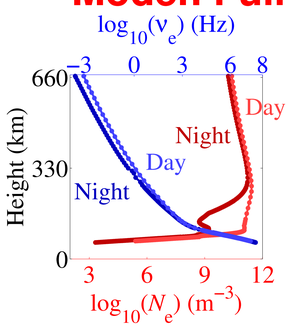
Data: DEMETER and NLDN

- DEMETER: Satellite to study ionosphere and EM spectrum
  - Orbit: Sun-synchronous, circular, 660 km
  - Instrument: Horizontal E and B at 40 kHz (below, right).
- NLDN: Lightning detection network over USA



We identified **>20,000 whistlers** in 14 night and 7 day passes.

Model: Full Wave Method

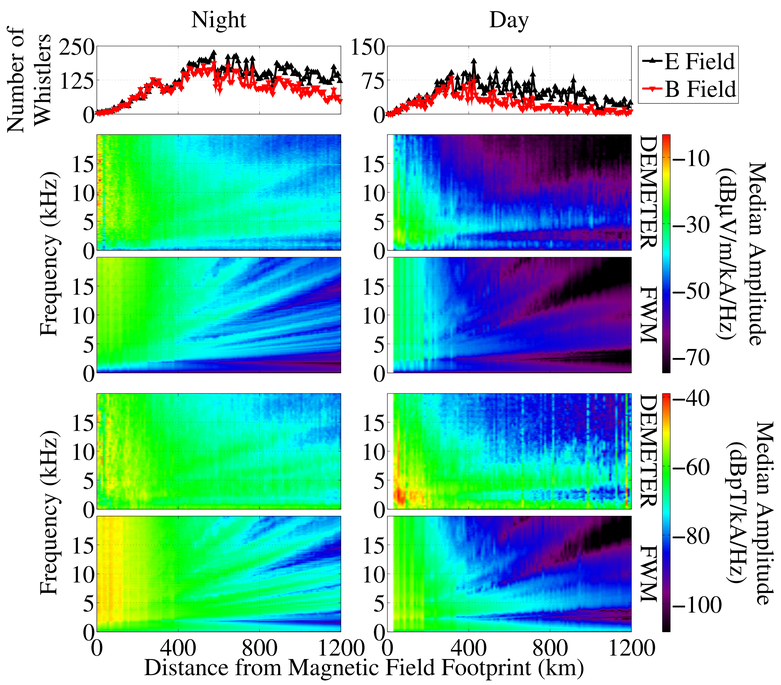


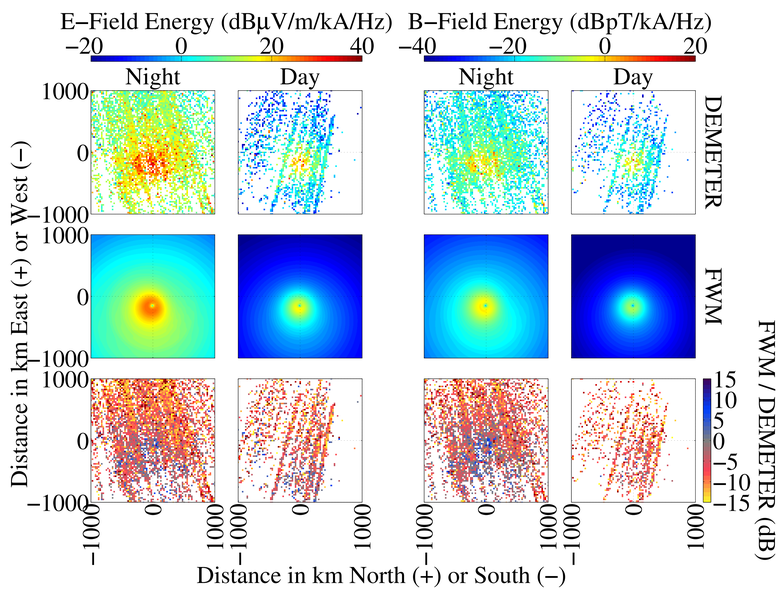
Ionosphere is split into horizontally stratified layers each with different $\overleftrightarrow{\epsilon}$ (a function of electron density N_e, collision frequency ν_e, and Earth's magnetic field, which we get from the IRI and IGRF). The lightning stroke is modeled as a point source Bruce and Golde current moment.

Median Amplitude over Horizontal Distance

We sorted the whistlers by the distance from their parent lightning stroke to the magnetic footprint of the DEMETER satellite and grouped them into 10 km-spaced bins. Then, we took the median field amplitude at each frequency for all the bins. The results are to the right.

The streaks going up in frequency with increasing distance are the same as the "V-shaped" streaks observed in DEMETER survey mode data after the satellite passed over a lightning storm. They are caused by a mapping of the Earth-ionosphere waveguide interference pattern to the satellite altitude. The simulation reproduces the streaks well.





Whistler Energy over Horizontal Displacement

To the left, we compare the total whistler energy between 2 kHz and 20 kHz. That is:

$$\int_{2\ \mathrm{kHz}}^{20\ \mathrm{kHz}} |X(f)|^2 \mathrm{d}f$$

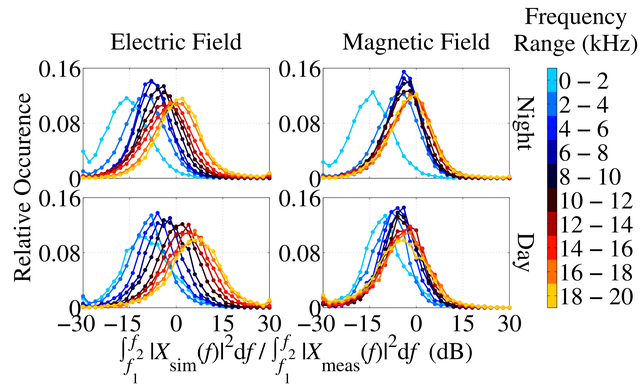
where $X(f)$ is either the simulated or measured electric or magnetic field normalized by the parent lightning peak current. The lightning stroke source is placed at the origin.

The peak in whistler energy occurs slightly south of the lightning stroke, which is in the direction of Earth's magnetic field in this hemisphere.

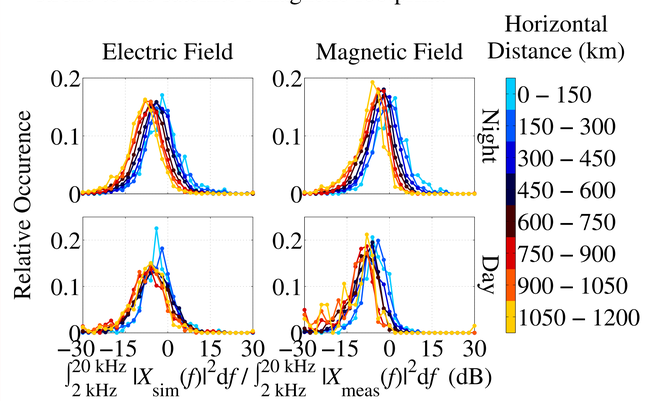
Histograms of All Observed Whistlers

Two trends in the results are worth highlighting:

1. Below, we compute the energy in various 2 kHz wide frequency rages and histogram the ratio between the simulation and measurements for all the whistlers:



2. Next, we compute the full whistler energy but group the whistlers according to the distance from the parent lightning stroke to the satellite's magnetic footprint:



Conclusions

Our simulations underestimate the field amplitudes measured by DEMETER by as much as 6 dB. Likely, the simulation is overestimating loss in the propagation through the ionosphere. The predicted field amplitude is closest to matching the satellite measurements for close lightning strokes, which could be due to modification of the ionosphere by lightning. Finally, the electric fields predicted by the simulation show a relative increase with increasing frequency that is not present in the magnetic field, which possibly indicates conversion to quasi-electrostatic waves.